

Resistance Welding of Butted Rings

By Eric Matwe



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Table Of Contents

Introduction.....	page 1
Welding Precautions.....	page 2
Included In this Kit.....	page 3
Setting Up Your Welder.....	page 4
Power Source	
Electrode Assembly	
Timing Circuit.....	page 5
Optional Variac	
Welder Diagram.....	page 6
Circuit Diagram.....	page 7
How Resistance Works.....	page 8
Resistance	
Current	
Voltage	
The Weld Cycle.....	page 9
Squeeze Time	
Weld Time	
Hold Time	
Welder Variables.....	page 10
Electrode Position	
Weld Duration	

Material Variables.....	page 11
Cleanliness	
Wire Diameter	
Aspect Ratio.....	page 12
Cuts	
Operator Variables.....	page 13
Pressure	
Electrode Maintenance	
Commonly Used Metals.....	page 14
Iron & Steel	
Brass & Bronze	
Niobium & Titanium.....	page 15
Aluminum, Copper, Silver & Gold.	
Types Of Welds.....	page 16
Solid Welds	
Upset Welds	
Flash Welds	
Bad Welds.....	page 17
Examples Of Welded Rings.....	page 18
Weld Strength.....	page 19
Conclusion.....	page 20

Introduction

This document is intended to be a practical guide to welding butted rings using a resistance welder. It is being distributed as a companion to the resistance welder kit designed by the author and distributed through TheRingLord.com's website. The information presented throughout this document will be referring specifically to those resistance welders but may also apply to resistance welders in general.

This is not a user manual, please take the time to read the instructions and safety precautions in the original equipment manufacturer (OEM)'s user manual that came with your welder.

Welding Precautions

As with any electrical device be aware that electrical shocks can potentially be fatal. Don't operate the welder in damp or wet conditions or expose it to water. Don't let your body touch a grounding surface while operating the welder. Inspect electrical components for damage before using the welder. Be aware that the electrodes are live during operation of the welder.

The electrical currents involved in welding create a strong magnetic field. This magnetic field can disrupt electronics and medical devices such as pacemakers. Any person who uses such a medical device should consult with their physician before attempting to use any welding equipment.

Resistance welding involves heating metal to near its melting point. Too much heat can cause an expulsion of sparks and molten metal droplets. Do not operate your welder near anything flammable, or with children or pets nearby.

Your welding kit contains a pair of heat resistant gloves to wear while welding. You may also want to buy a clear plastic face shield to protect your face and eyes from stray sparks. It is best to wear clothing that fits well and covers your arms, legs and feet to avoid burns. Avoid open toed shoes, sandals and low cut necklines. Synthetic fibres and terrycloth catch fire easily from sparks, do not wear them.

Included In This Kit

1. 115V AC resistance welder transformer
2. Electrode assembly
 - a) 2X Mounting arms
 - b) 2X Brackets
 - c) 4X M6 nuts & bolts
 - d) 2X M8 nuts
 - e) 2X SH16516 rings
 - f) 2X copper terminals
 - g) 2X 6" copper cable
 - h) 2X electrodes
 - i) 4X insulating washers
3. Timing assembly
 - a) Timer
 - b) Foot switch
 - c) Power cord
 - d) 4X clear terminals
 - e) #10-32 bolt
 - f) 2X yellow terminals
4. 1 pair heat resistant gloves
5. Sample welded rings
6. OEM Manual
7. Resistance Welding of Butted Rings booklet

Setting Up Your Welder

Power Source

The power source for the welder is a commercially available resistance welder transformer. The welder has been tested before shipping and the test welded rings have been included with your kit. Many of the OEM parts have not been assembled or included with your resistance welding kit because they are unusable for welding rings. For further information or questions review the OEM user manual for this welder that shipped with your welding kit .

Due to safety concerns we have not modified the electrical circuit in any way. You may install the timing circuit on the welder and remove the OEM switch if you choose to do so. Instructions are provided in this document.

Electrode Assembly

Please note that the OEM electrode assembly is not included with the welding kit. A new electrode assembly has been purpose built for TheRingLord.com and has been mounted to the front of the welder. This electrode assembly is intended to be adjustable for welding butted rings with inner diameters ranging from 1/16" to 1". Adjust the electrodes by rotating the adjustable arms they are mounted on. If you intend to weld rings outside this range you may need to modify or replace the electrode assembly.

Timing Circuit

To install the timing circuit, it should be bolted through the center hole to the welder body. Be sure that both the timing circuit and the welder's power source are unplugged before proceeding. Disconnect the OEM switch from the wires and crimp the supplied yellow terminals to the stripped ends of the wires, then connect those terminals to the matching relay terminals on the timer. For illustration refer to page 6 fig. 1-1 and page 7 fig. 1-2.

Turn the potentiometer knob on the timer to adjust the duration of the weld. The duration is adjustable between 0.02 and 2 seconds and is actuated by the foot pedal. The expected lifespan of the timer relay is at least 500,000 welds and probably more.

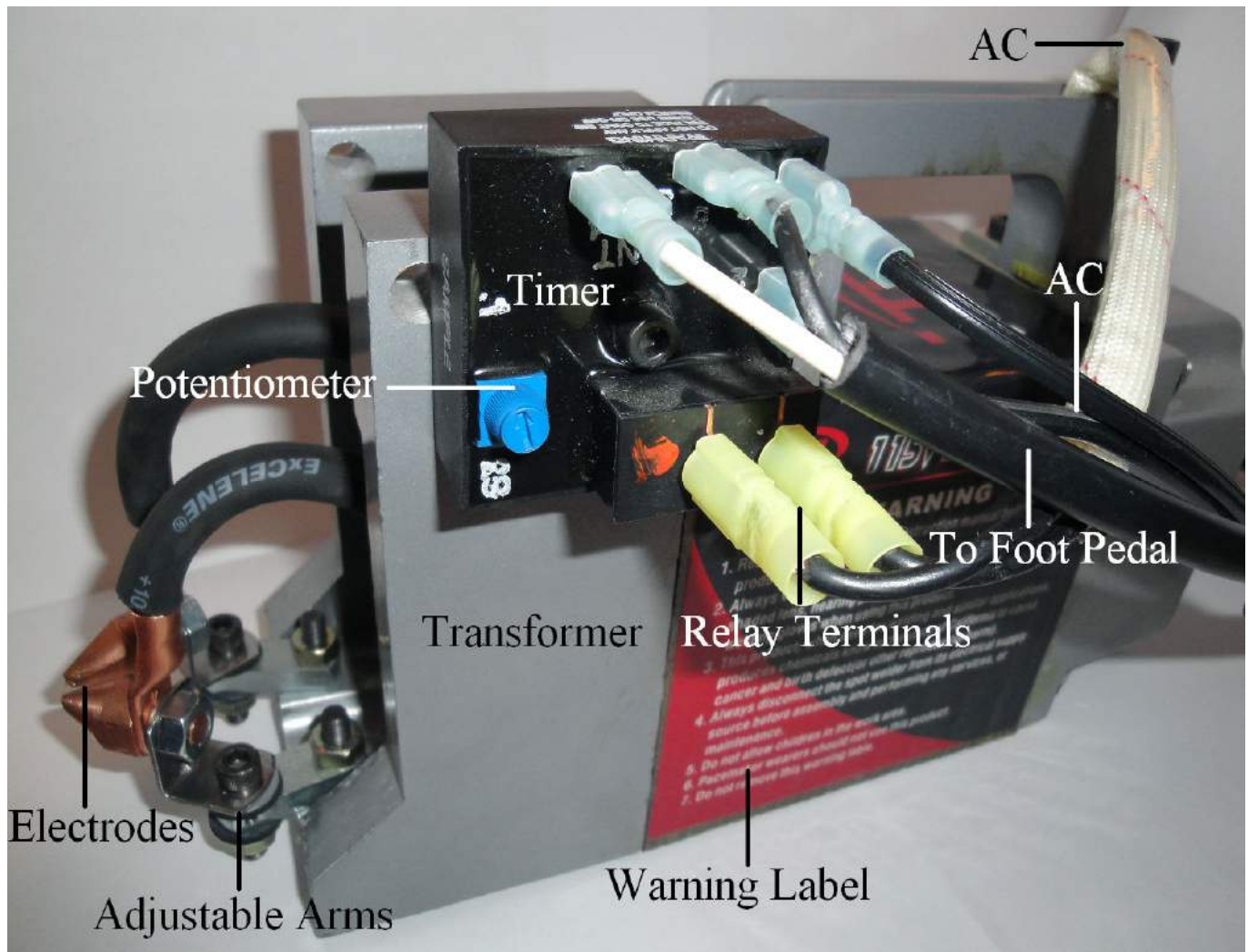
Optional Variac

If you have a Variac you may plug the welding power source into it to allow control of the weld voltage. Be sure that you don't set the Variac higher than 115V. The welder is designed to handle 115 Volts which is, on average, what a North American outlet supplies. The actual voltage supplied in North America can vary widely between 100-130 Volts depending on many factors.

A Variac enables consistent welds on very small rings. Decrease the voltage to decrease the heat of the weld. Due to the construction of the timer relay the welder will probably not function below a certain voltage.

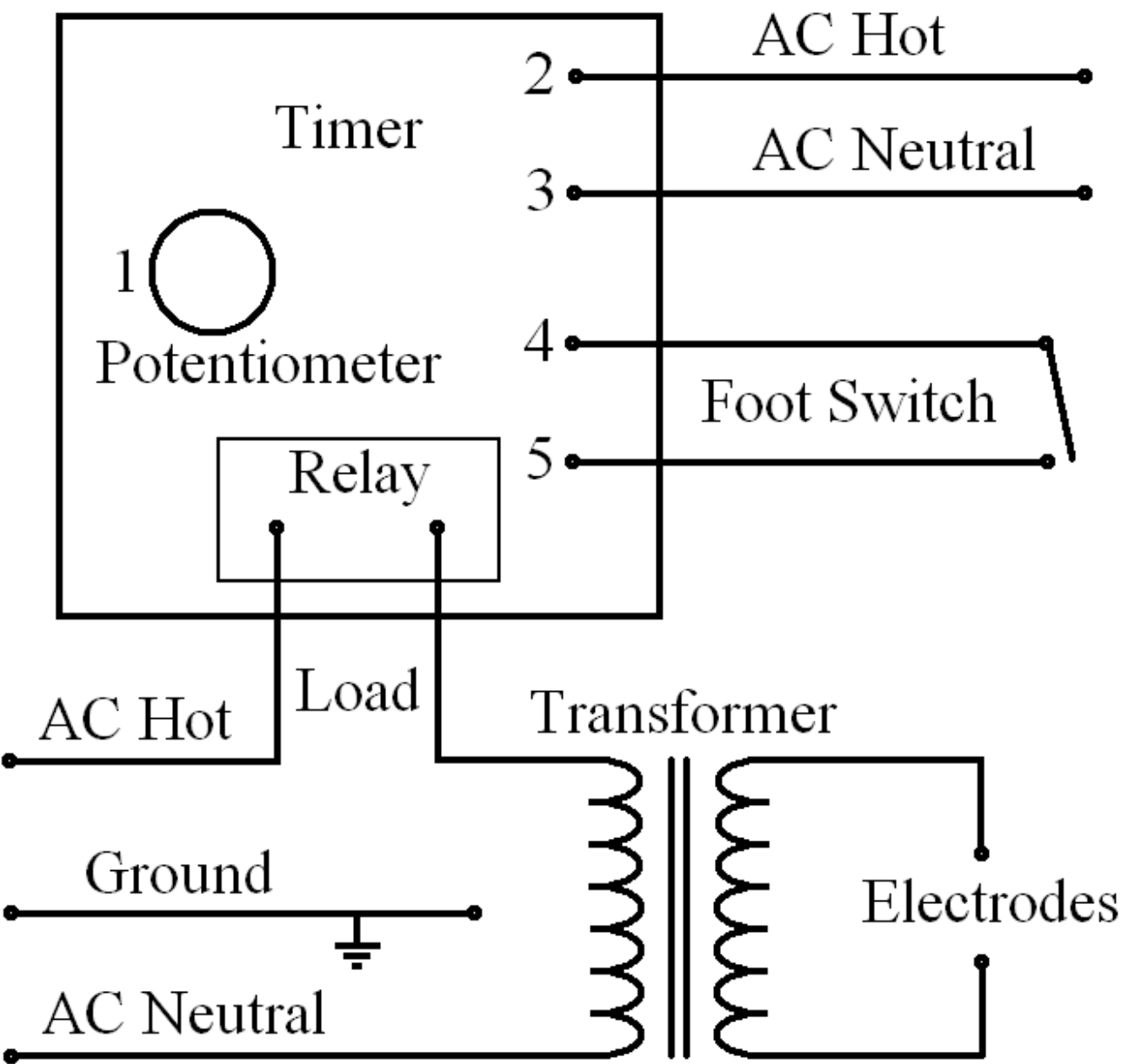
Welder Diagram

Fig. 1-1



Circuit Diagram

Fig. 1-2



How Resistance Works

Resistance

Resistance, measured in Ohms, is the opposition of an electrical circuit to the flow of current. It is calculated by dividing the voltage by the current. Resistance is what heats the ring so it is very important that the point in the circuit with the highest resistance is the butted joint of the ring.

Current

Current, measured in Amperes and abbreviated Amps or just A, is the amount of electricity that is flowing through an electrical circuit. A standard household socket in North America can supply ~15A, but it takes several hundreds or thousands of Amps to make a resistance weld. The welder power source is a transformer that increases the amperage of the electricity to a level where the resistance can heat the ring to welding temperature.

Voltage

Voltage, measured in Volts and abbreviated V, is the force that causes the current to flow. When the amperage is increased by the transformer the voltage decreases inversely. Increasing or decreasing the voltage will also increase or decrease the heat of the weld.

The Weld Cycle

Squeeze Time

A resistance weld is separated into 3 distinct phases. First there is the squeeze time. This is the period of time just before current is applied when the operator presses the ring against the electrodes with a constant pressure.

Weld Time

The second phase is the weld time. During this phase the operator maintains the pressure on the ring while applying current. This heats the metal of the ring to a plastic or liquid state and forces the ends together creating the weld.

Hold Time

The third and final phase is the hold time. This phase begins as soon as the current has stopped flowing through the ring. During this phase the operator must continue to maintain pressure against the ring until the metal has cooled to the point where it is solid again.

Welder Variables

Electrode Position

The position of the electrodes is adjusted individually keeping them as symmetrical as possible. You can change both the angle at which the electrodes contact the ring and the distance between the electrodes.

It's important to angle the electrodes so that when pressure is applied most of the force presses the ring against them but a significant fraction also presses the ends of the ring together.

The greater the distance between the electrodes the higher the resistance in the wire will be and the less concentrated the heat will be on the butted area to be welded. This can be useful for some ring sizes but will create a larger heat affected zone (HAZ) on the ring. In general it is best to keep the gap between electrodes relatively small but wide enough that the electrodes don't become overheated. The gap can be precisely adjusted using shims.

Weld Duration

Weld duration is adjusted via the potentiometer knob on the timer. Increasing the amount of time enables the operator to heat larger rings to their welding temperature. Decreasing the time gives more control for smaller rings and less resistive metals. I suggest marking the positions of your most frequently used settings.

Material Variables

Cleanliness

Any contaminants on the ring's cut area, such as dust, oil, or oxides can interfere with getting a good weld. In some cases contaminants can prevent any welding or cause the welds to become very brittle. Freshly cut rings are usually free of contaminants but saw cut or machine cut rings may have residual oil or grease from lubrication. Ultrasonic cleaners are the best way to remove contaminants from cuts. Washing with detergent and water is also usually effective.

Conversely, purposely contaminating a weld joint can be used beneficially to create more resistance or prevent oxidation in difficult to weld metals. This is an advanced technique and specific details are usually guarded as trade secrets.

Wire Diameter

The thickness of the wire affects the resistance; thinner wire will have more resistance and therefore require less heat and time to weld. Thicker wire transfers more heat away from the weld area and is stronger requiring more heat and pressure to weld properly. Trying to weld wire larger than 12g is possible but can result in problems such as operator fatigue, damaged electrodes and shortened welder life.

Aspect Ratio

The aspect ratio (AR) of a ring is the ratio of its inner diameter to the diameter of the wire. As the aspect ratio decreases the ring will require more pressure to weld properly. Rings with an aspect ratio of 4:1 or less may be difficult for some people to weld. As the aspect ratio increases or decreases the electrodes should be adjusted outwards or inwards to compensate for the changing angle between the ring and electrodes.

Cuts

Pinch cut rings have the highest resistance at the cut so they start a weld easily but have problems with the ring ends slipping off each other as they melt under pressure. This usually results in off round rings and large burrs in the weld. The welds are generally strong and with aggressive tumbling are good for armor.

Shear cut and machine cut rings are of roughly equal quality. They weld easily and don't slip often, resulting in a more rounded ring. Because the ends are more flush they generally have smaller burrs and more consistent welds can be made. These types of rings are ideal for most applications.

Saw cut rings can be a little more difficult to weld since the cut has lower resistance, however these rings give the nicest looking welds with little to no burring. If you are making jewelry then these are definitely the rings you want. Be aware that due to the gap between the ends these rings will become more ovoid than shear cut rings.

Operator Variables

Pressure

There are two variables that must be controlled manually by the operator. The first variable is pressure. As pressure is increased resistance will decrease. The more pressure that is applied between the ring and the electrode the less heat will be generated there and the more heat will be generated directly between the butted ends. This helps minimize the heat affected zone and also presses the butted ends together ensuring a good weld.

It is important to apply consistent pressure to the ring throughout the three phases of the weld cycle. Too much pressure will create a large burr or misalignment in the weld. Too little pressure will result in brittle welds.

Electrode Maintenance

The second variable is electrode maintenance. Keeping the electrodes clean and undamaged ensures correct alignment of the ring's ends and low resistance between the ring and electrodes. Electrodes should be cleaned and repaired by dressing them lightly with a fine toothed triangular file.

When the electrodes become badly worn or damaged they must be replaced. TheRingLord.com has replacement electrodes available.

Commonly Used Metals

Iron & Steel

Iron and iron alloys, notably the various types of steel, are the most commonly welded metals. These metals resistance weld easily. The corrosion resistance of stainless steel will be somewhat reduced during the welding process but can be mostly restored by polishing off the oxide layer. Resistance welds made in steel or iron should be stronger than the original wire. Steel alloys with a large amount of carbon may need special heat treating after they have been welded, otherwise the heat affected zone can become very brittle.

The fumes produced from welding galvanized or zinc chromate plated steel are toxic and will make you very sick. Do not weld these materials.

Brass & Bronze

Brass and bronze are copper alloys. Copper is a very low resistance metal, which is why the welder's electrodes are made from it. Very good resistance welds can be made with most copper alloys but the weld timer will need to be set for shorter periods compared to iron alloys. Using a Variac to decrease the voltage is useful for smaller wire sizes. With practice the welds in either metal can be made stronger than the original wire but in many cases it's more practical to make welds that are just strong enough for the application.

Titanium & Niobium

Titanium and niobium are reactive metals. When heated in air they readily form brittle oxides with atmospheric oxygen. In most welding processes they cannot be welded unless they are covered with inert gases such as argon or helium. Resistance welding is an exception.

By using very fast weld times and high pressure, the metal can be welded before it has a chance to oxidize. This technique is also known as a solid state bond, since the metal will not be entirely molten when welded. Some oxides will form but the pressure of the weld should help to expel them from the weld joint.

Reactive metals are relatively expensive and when welding them you should expect a higher than normal amount of bad welds. Keep this in mind when estimating material costs. In many cases it may be less expensive to use inert gas shielding for consistently good welds.

Aluminum, Copper, Silver & Gold

In theory any metal can be resistance welded but in practice some are just too difficult without very expensive equipment. The metals that are most difficult to weld are silver, gold, copper, and aluminum, in that order. All of these metals have very low resistances and tend to melt or blow apart when you try to weld them. Silver and gold in particular should not be resistance welded since they are much more expensive and also very easy to solder or braze.

Types Of Welds

Solid Welds

Solid welding refers to the technique of setting the heat or weld time lower than normal to create a weld area where there is little to no flow of metal. A solid weld is most useful for cosmetic purposes when working with saw cut rings. It can be a full strength weld but is more likely to be 60-90% strength, which is still many times the strength of a butted ring. Precise settings and low pressure are required to get good solid welds. See page 18 fig. 2-1.

Upset Welds

Upset welds are the preferred welds for most applications, they are usually stronger than the wire the ring is made from. To make an upset weld you must ensure that there is enough heat and pressure so that the metal becomes plastic when it is forced together and creates a widened (upset) area around the welded joint. During this process any oxidation is squeezed outwards from the weld area in a similar manner to forge welding. See page 18 fig. 2-2.

Flash welds

Flash welds are a result of the upset area liquefying due to extra heat and pressure and forming a large circular burr, known as flash. This is a strong weld in most metals but the ring will be more oval shaped and the flash may chafe against skin. Usually the flash can be smoothed off to an acceptable level. See page 18 fig. 2-3.

Bad Welds

There are many types of bad welds and combinations thereof; I've listed a few of the most common. They usually have a major drawback for typical uses.

Tack welds look similar to a solid weld but are more brittle. They are caused either by contamination of the weld or by not enough weld heat. Tack welds may be acceptable for some non-strength critical applications. Trying to re-weld tack welded rings seldom results in a good bond. See page 18 fig. 2-4.

Misaligned welds occur when the ends slip away from each other during the weld time. Alignment problems can normally be resolved by proper electrode adjustment. They are not much weaker but can chafe and are an eyesore in jewelry because they are off round. A slight misalignment or burr can often be flattened by squeezing it between the jaws of smooth faced pliers. See page 18 fig. 2-5.

Burnt welds are caused by too much weld time without sufficient pressure. In these welds the metal has been overheated and begun to oxidize, this causes at least a portion of the weld area to turn to slag. The metal in the weld area will usually sag or crumble. In extreme cases a large section of the ring can liquefy and spray droplets of molten metal. If the welds are only slightly burnt and not yet brittle then they may be used for applications where appearance is not a concern. See page 18 fig. 2-6.

Examples of Welded Rings

Fig. 2-1*



A typical solid welded ring.
Before and after strength test.

Fig. 2-2*



A typical upset welded ring.
Before and after strength test.

Fig.2-3*



A typical flash welded ring.
Before and after strength test.

Fig. 2-4



A typical tack welded ring.
Before and after strength test.

Fig. 2-5*



A typical misaligned welded ring.
Before and after strength test.

Fig. 2-6



A typical burnt welded ring.
Before and after strength test.

*Denotes strength tested rings which were badly deformed and required flattening to improve image quality.

Weld Strength

Weld strength can be tested by pulling and twisting the ring between two pairs of pliers until it breaks or deforms. Always test the strength of your welds after changing a welder or material variable. When making armor it is a good idea to periodically test the strength of your welds while you work.

If the ring breaks on the weld with no deformation of the ring then it is less strong than the yield strength of the wire. This indicates a tack weld which usually has much less than 50% of the strength of the wire.

If the ring breaks on the weld with some deformation of the ring then the weld is stronger than the yield strength of the wire but less strong than the ultimate tensile strength of the wire. This is typical for solid welds in most metals and flash welds in Ti and Nb. These welds are fine for some applications, in commonly welded alloys they will generally have between 60-90% of the strength of the strongest welds.

If the ring breaks in a spot that is not on the weld then the weld is stronger than the ultimate tensile strength of the wire. This is the strongest that any welded ring can be, the weld strength is 100% or higher. The ring will usually break on the wire directly adjacent to where it has been clamped.

Conclusion

Welding is a complex process which requires practice and skill. I have compiled most of the basic principles of resistance welding, as they apply to butted rings, but there is much more to learn that falls outside the scope of this document.

TheRingLord.com's discussion forum is there for you if you have problems using your resistance welding kit or want to share your own tips with other users.

<http://www.theringlord.org/forum/Index.php>

On the forum you can interact with other users of the resistance welding kit or get help directly from TheRingLord.com's professionals.

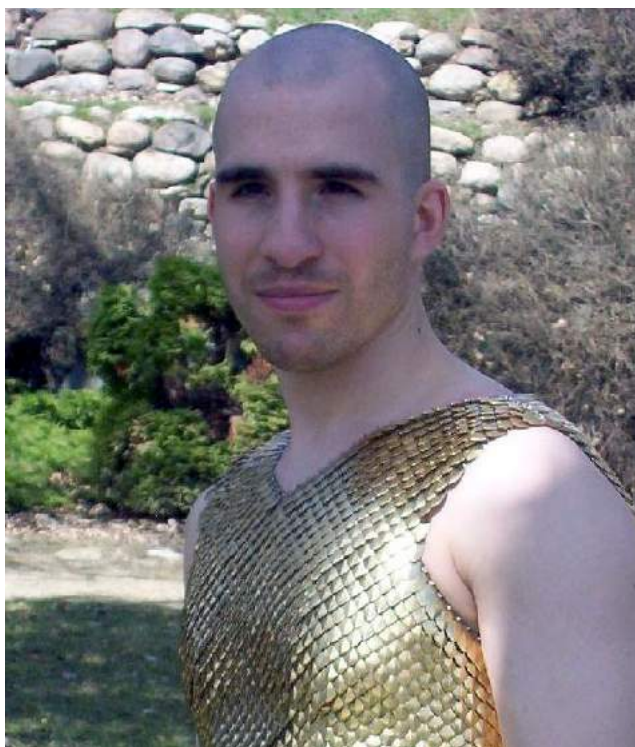
As an active member on the website I look forward to meeting you there.

Eric “lorenzo” Matwe

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This image shows a single page of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page, leaving small margins at the top and bottom. There are no vertical margin lines or other markings on the page.

About the Author



Eric Matwe is a professional maille craftsman who specializes in welding and automated production techniques.

He has 5 years experience working at TheRingLord.com and 3 years experience repairing maille armor for the meat packing industry.

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